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16. ABSTRACT

This is the second EPA report to Congress on federal research required biennially under Section 153(g) of the Clean Air Act Amendments of 1977 (Public Law 95-95). It emphasizes the findings of EPA-supported research and related studies and presents the latest assessment and understanding of stratospheric ozone depletion by chlorofluorocarbons as reported by the National Academy of Science in 1979. This EPA report does not describe all the relevant research results obtained by other federal agencies since Section 154 of the Clean Air Act requires them to submit separate reports, but their results are incorporated to the extent possible. Research supported by EPA has focused on analyzing the effects of increased UV-B exposures on humans and nonhuman biological systems. The potential for significant adverse environmental effects has been suggested by research accomplished to date. It has been established that additional research, both short- and long-term, is needed to identify and quantify the direct and indirect effects of ozone depletion in all areas--human health, other biological/ecological systems, climate monitoring, economics, and social issues.

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Prepared for

96th Congress of the United States

Prepared by

Office of Research and Development
Washington, DC 20460

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PREFACE

This report is submitted to Congress in compliance with Section 153(g) of the Clean Air Act Amendments of 1977, Public Law 95-95 (PL 95-95). The law requires that the Administrator of the Environmental Protection Agency, as part of the program for ozone protection, shall "not later than January 1, 1978, and biennially thereafter, . . . report to the appropriate committees of the House and the Senate, the results of the studies and research conducted under this section and the results of related research and studies conducted by other Federal agencies."

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I EXECUTIVE SUMMARY

A. Introduction

Concern over the possible depletion of stratospheric ozone due to the release of chlorofluorocarbons (CFC's), as well as by other emissions and activities of mankind, has existed for several years. In August 1977, Congress passed PL 95-95, the Clean Air Act Amendments of 1977, which includes a mandate for EPA to undertake and coordinate federal research to ascertain impacts of ozone depletion on public health and welfare, and human-generated causes of such depletion. This document is the second report on federal research required biennially under section 153(g) of PL 95-95.

B. Findings to Date--An Overview

This report emphasizes the results of EPA-supported research and related studies and presents the latest assessment and understanding of stratospheric ozone depletion by CFC's, as reported by the National Academy of Sciences in November 1979 ("Stratospheric Ozone Depletion by Halocarbons: Chemistry and Transport"), and in December 1979 ("Protection against Depletion of Stratospheric Ozone by Chlorofluorocarbons"). This EPA report does not describe all the relevant research results obtained by other federal agencies, since Section 154 of the Clean Air Act requires them to submit separate reports. Reports from these other federal agencies to the Congress complement the present document. To the extent possible, their results are integrated into this summary.

The resulting effects of uncontrolled release of ozone-depleting substances to the atmosphere has far-reaching implications and are not limited to the United States, but are distributed globally. Many uncertainties and unknowns still exist in each research area, though the NAS has expressed its conclusion that it has a 95% confidence that existing rates of CFC emissions will result in an ozone depletion of between 5 and 28%. The general objective of the research to date has been to reduce these uncertainties, probe into certain areas where knowledge is meager, and quantify ozone-depletion effects wherever possible.

Recent research suggests that if chlorofluorocarbon (CFC) releases were to continue at the 1977 rate, a stratospheric ozone depletion of about 16.5% could occur in three to five decades. This would affect the transfer of solar energy in the atmosphere. Current capabilities to assess the impact of such depletion on weather and climate are limited to approximate predictions of globally-averaged temperature increases. (The current predicted increase is about $0.4^{o}C$.) However, ozone depletion could also affect local and regional weather, including precipitation. Unfortunately, lack of knowledge on this issue limits the ability to make useful predictions.

Since the stratospheric ozone layer shields the earth's atmosphere, surface, and waters from damaging ultraviolet wavelengths between 290 and 320 nm (UV-B), the estimated ozone depletion of 16.5% will also result in substantial increases (about 33% for mid-latitudes) of UV-B dosages to exposed biological systems. Therefore, much of the current research supported by EPA has focused on analyzing the effects of increased UV-B exposures on humans and nonhuman biological systems.

Since humans are not exposed experimentally to controlled dosages of UV-B, assessments of the effects of UV-B exposure on human health are largely based on demographic studies in eight regions by the National Cancer Institute (NCI), supported by EPA, using epidemiological data. The emphasis has been on analyzing skin cancer incidence rates. The most significant health finding to date that NCI will report is that, for the United States as a whole, a 4-fold increase in non-melanoma skin cancer rates correlates with a 2-fold increase in UV-B radiation flux. Measurements by the National Oceanic and Atmospheric Administration (NOAA) indicate that each 1% decrease in ozone results in a 2% increase in UV-B radiation. Future studies will attempt to refine the above findings and quantify the relationship between melanoma (about 50% mortality rate) skin cancer and UV-B radiation.

Other biological (ecological) systems have been experimentally exposed to controlled dosages of UV-B. Nevertheless, the problem of quantifying these biological effects is enormous. Only a few major plant and animal groups, primarily fish and phytoplankton, have been studied during this reporting period. In spite of this limitation, recent research leads to the following conclusions:

- Small increases of UV-B appear to inhibit photosynthesis in some terrestrial and aquatic plants and at least some nitrogen fixing mechanisms.
- Plant species possess the capability for some repair of UV-B damage when exposed to full sunlight in the visible portion of the spectrum but this repair does not prevent significant reductions in the yields of sensitive species.
- Shifts in the composition of both aquatic and terrestrial plant and animal communities are probable, and some of these shifts appear likely to significantly damage commercial fisheries.

It can thus be stated that an increase of UV-B radiation at the earth's surface resulting from stratospheric ozone depletion would probably have ecological impacts. However, there is a lack of means to assess and predict the sensitivity of various ecological systems to increased UV-B radiation. Further effort is necessary to quantify such sensitivity before social and economic impacts can be estimated.

Improved instrumentation and monitoring are vital to research on ozone-depletion impacts. A portion of the funds available for this research has been spent on development of (1) improved UV-B sources and instrumentation, (2) additional UV-B monitoring, and (3) analysis of the resulting data base. A small portable personal dosimeter has been developed and delivered for use in health effects research in order to better quantify the exposure of individuals to UV-B radiation in contrast to measuring the UV-B radiation flux to a geographic location. In an effort to improve the accuracy of a variety of UV-B sources and detectors, the National Bureau of Standards (NBS) has established a quality-assurance procedure (and is out-fitting a laboratory) that will ultimately reduce measurement errors to less than 10%. (Currently these range as high as 45%.)

Additional UV-B monitoring (Item 2, above) was undertaken by NOAA at the key epidemiological locations, as identified in the NCI skin cancer studies. Under Item 3, above, analysis of existing NOAA data has resulted in a verification that the ratio between UV-B enhancement and ozone depletion is very close to the theoretically predicted value of 2 (i.e., a 2% increase in UV-B for every 1% decrease in ozone).

Again, it is emphasized that more data and research are needed to reduce further the uncertainties associated with estimation of impacts caused by ozone depletion.

C. Future Research Needs

A potential for significant adverse environmental effects has been suggested by research accomplished to date. Examples are skin cancer incidence, effects on larvae of commercially important fishes, marine organisms such as phytoplankton and zooplankton, and certain plants used as food. More data are needed in all areas (i.e., human health, other biological/ecological systems, climate monitoring, economics, and social issues). The general research requirements are outlined here.

Research needs are separated into short-term and long-term programs. Short-term programs are those that will return substantial quantitative knowledge within a one- to three-year period. The longer-term research program objectives are to broaden the base of knowledge and further reduce uncertainties and to identify and quantify the direct and indirect effects of ozone depletion on human health, and ecological, geophysical and socio-economic systems.

II CAUSES OF STRATOSPHERIC OZONE DEPLETION AND RESULTING ENHANCEMENT OF ULTRAVIOLET RADIATION

A multitude of theoretical and experimental research and monitoring of stratospheric chemical and physical processes and constituents has been and is being conducted nationally and internationally. Such studies during the two-year period (1978 and 1979) covered by this report have especially increased our knowledge on the subject of the impact of man's activities, particularly the release of CFC's, on stratospheric ozone. The National Aeronautics and Space Administration, National Oceanic and Atmospheric Administration, Department of Transportation, National Science Foundation and the Environmental Protection Agency are the government agencies principally supporting such atmospheric studies. The other agencies are reporting their activities separately to the Congress in accordance with Section 154 of the Clean Air Act Amendments of 1977.

The evaluation of those research findings and their implications are presented in two reports just completed by the National Academy of Sciences (NAS) after a lengthy and detailed analysis and assessment. The NAS effort was contracted by the EPA, in accordance with Section 150 of the Clean Air Act Amendments of 1977. The reports (enclosed) are titled "Stratospheric Ozone Depletion by Halocarbons: Chemistry and Transport" and "Protection against Depletion of Stratospheric Ozone by Chlorofluorocarbons."

The report "Stratospheric Ozone Depletion by Halocarbons: Chemistry and Transport" concerns itself with: Sources of Stratospheric Chlorine; Atmospheric Chemistry; Atmospheric Transport; Inactive Sinks and Their

Assessment; Global Ozone Observations; Atmospheric Measurements; Theoretical Models of the Stratosphere; Ozone Change Projections; and The Treatment of Uncertainties.

Its principal findings are:

- There is agreement with previous reports that continued release of halocarbons into the atmosphere will result in a decrease in stratospheric ozone.

- New values for some of the chemical rate coefficients have increased the predicted ozone reduction resulting from continued release of chlorofluoromethanes (CFM's).

- The most probable value calculated for the eventual ozone depletion due to continued release of CFM's at the 1977 level is 16.5 percent. This value is obtained from the value of 18.6 percent calculated from the computer model by allowing for possible tropospheric sinks for CFM's and for the effects on stratospheric chemistry of the CFM greenhouse effect.

- There have been considerable improvements in the computer models and in the laboratory and atmospheric measurements, which have reduced the uncertainty range.

- Although there are a few exceptions, the comparison between the models and measurements of substances in the present stratosphere is considered to be satisfactory within the uncertainties of the measurements. We therefore believe that the projections for ozone depletion are valid within the stated uncertainty ranges.

- The uncertainties in the chemical rate coefficients, in atmospheric transport, and in the use of one-dimensional models have been combined to give an overall uncertainty range of a factor of 6 within a 95 percent confidence level.

- The uncertainty range means that for the case of continued release of CFM's at the 1977 level there is 1 chance in 40 that the ozone depletion will be less than 5 percent and 1 chance in 40 that it will be greater than 28 percent.

- Even allowing for the best professional judgment of the possibility that some important chemical reaction has been overlooked or that there remain large errors in the measured chemical rate coefficients, we believe that there is a 3 out of 4 chance that continued release of CfM's at

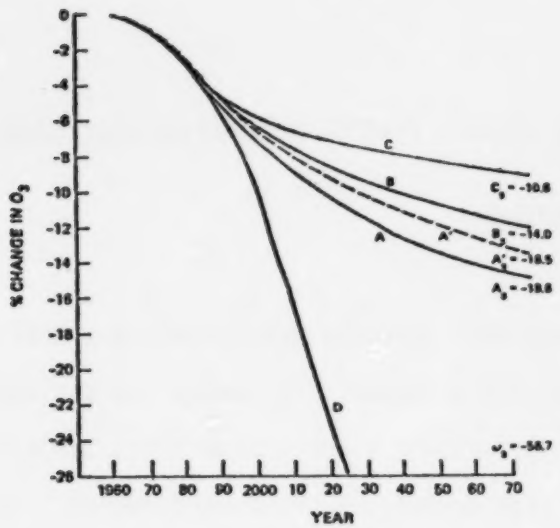
the 1977 level will result in an ozone depletion that lies in the range of 9 to 24 percent.

- If the rapidly increasing use of F-22 (CHF_2Cl) and methyl chloroform (CH_3CCl_3) continues unabated, the release rates and atmospheric behavior of these compounds will require careful attention. However, since chemical reactions remove appreciable fractions of these compounds before they reach the stratosphere, substitution of F-22 for F-11 ($CFCl_3$) and F-12 (CF_2Cl_2) would be beneficial.

- It is unlikely that direct measurements of the average global ozone amount would permit detection of a decrease of less than 5 percent attributable to human activity. Total cessation of CFM release at the time of detection would result in a decrease of ozone of about 7 percent some 15 years later.

The report "Protection against Depletion of Stratospheric Ozone by Chlorofluorocarbons" concerns itself with two important topics: (1) Causes and Effects of Stratospheric Depletion (including Nonhuman Biological Effects; Human Health Effects; Climatic Impact of Stratospheric Change; and Biologically Effective Ultraviolet Radiation); and (2) Alternatives for the Control of Chlorofluorocarbon Emissions and Options for Their Implementation (including International Aspects; Feasibility, Costs, and Impacts of Technological Alternatives; Regulatory and Socioeconomic Considerations; Technological Possibilities for Reducing CFC Emissions from Mobile Air Conditioning, Technological Possibilities for Reducing CFC Emissions from Plastic Foams; and Summary of Three Benefit-Cost Studies).

The NAS projected stratospheric ozone depletion by CFC's into the next century is presented here for elucidation (Figure 1). This projection, for several emission rate scenarios, when coupled with worldwide usage characteristics (the U.S. share of world CFC production/emission approximates 31%), indicates the global nature of the protection of stratospheric ozone.



Ozone reduction for various scenarios: A, constant release rate at the 1977 value; A_S, steady-state value = -18.6%; A', constant release rate at the 1977 value, same as A but multiplied by a factor of 0.89 to correct for feedback effects and the possible existence of a tropospheric sink; B, 1977 release rates until 1983, from then on reduced by 25%; B_S, steady-state value = -14.9%; C, 1977 release rates until 1983, reduced by 25% until 1988, reduced an additional 25% after 1988; C_S, steady-state value = -10.6%; D, 1977 release rates until 1980, increasing by 7% per year until 2000, then constant release rate at the year 2000 value; D_S, steady-state value = -56.7%.

FIGURE 1 PROJECTED STRATOSPHERIC OZONE DEPLETION BY CFC'S

III POTENTIAL PRIMARY EFFECTS OF STRATOSPHERIC OZONE DEPLETION

A. Human Health Effects

1. Background

It has long been accepted among physicians that there is a clear relationship between non-melanoma* skin cancer and sunlight exposure. These cancers were typically seen in light-skinned individuals who spend considerable time outdoors (for example, sailors and farmers). These cancers were also known to be rare in blacks. Attempts have been made to quantify this relationship--such as the calculation of annual incidence rates for locations at different latitudes--because:

- The relationship was so obvious that preventive measures could be justified, even in the absence of quantification.
- It is more difficult and tedious to calculate incidence rates for non-melanoma skin cancer than it is for other cancers, including melanoma. Most patients with the former disease do not require hospitalization and do not die from the disease. Therefore, in order to count every new case of this disease in a defined geographic area, cooperation of all physicians in that area (and nearby areas) is needed. This is considerably more difficult and tedious than obtaining the cooperation of the administrators of the much smaller number of hospitals in these areas and supplementing this information with a search of death certificates.
- While virtually all (98 - 99%) non-melanoma skin cancer cases are not fatal, the routinely available mortality rates cannot be used as a substance for incidence rates. In addition, death certificates listing non-melanoma skin cancer as the cause of death were often inaccurate (Dunn, et al., 1965).

*While virtually all of these cancers are either basal or squamous cell carcinomas, any type could be referred to as carcinomas of the skin. However, this "non-melanoma" terminology is prevalent in the literature and therefore is used in this report.

Even before concern about ozone depletion arose, exposure to sunlight had been widely suggested as being a cause of melanoma because similarities with non-melanoma skin cancer were so striking (although this relationship was not completely accepted). Lancaster (1956) was the first of many investigators to demonstrate that risk of melanoma increased as the equator was approached. He also was the first to conduct a case control study of melanoma (Lancaster and Nelson, 1957). Several case control studies have found that individuals at high risk had fair complexions and also spent a lot of time outdoors. However, these studies are unlikely to have explained the consistency of these conclusions because of problems inherent in the study design. European immigrants to Israel before 1948 have been found to have higher age and sex specific incidence rates than more recent European immigrants (Movshovitz and Modan, 1973). While some curve fitting of the data has been done, this information was used primarily as evidence that sunlight was involved in the etiology of melanoma rather than to determine a dose-response relationship.

2. Recent Research

a. Skin Cancer Data

Renewed interest in quantifying the risk of non-melanoma and melanoma skin cancer with exposure to ultraviolet was stimulated by the concern about ozone depletion. Establishment of a dose-response relationship is necessary in order to determine how many additional skin cancers could be predicted to occur as a result of predicted ozone depletion and resulting increased ultraviolet exposure and to support an integrated assessment for regulatory decisions.

In a determination of the dose-response relationship for the disease, several response measures are available, including:

- The incidence rate (the number of new cases of disease per unit population per unit time). For melanomas, these rates are available for 9 locations from the 3rd National Cancer Survey and are also available from Cancer Registries, including those participating in the Surveillance Epidemiology and End Results (SEER) Program. For non-melanoma skin cancer, NCI under EPA funding has calculated incidence rates at eight of the SEER locations (Scotto, 1979a). Previously, Scotto, et al. (1974) computed incidence rates at four TNCS locations. Both these data are plotted in Figure 2 (from Scotto, 1979). One Cancer Registry (Waterhouse, et al., 1976) claims to collect all newly-diagnosed non-melanoma skin cancer in their defined geographic area. They also publish these rates.

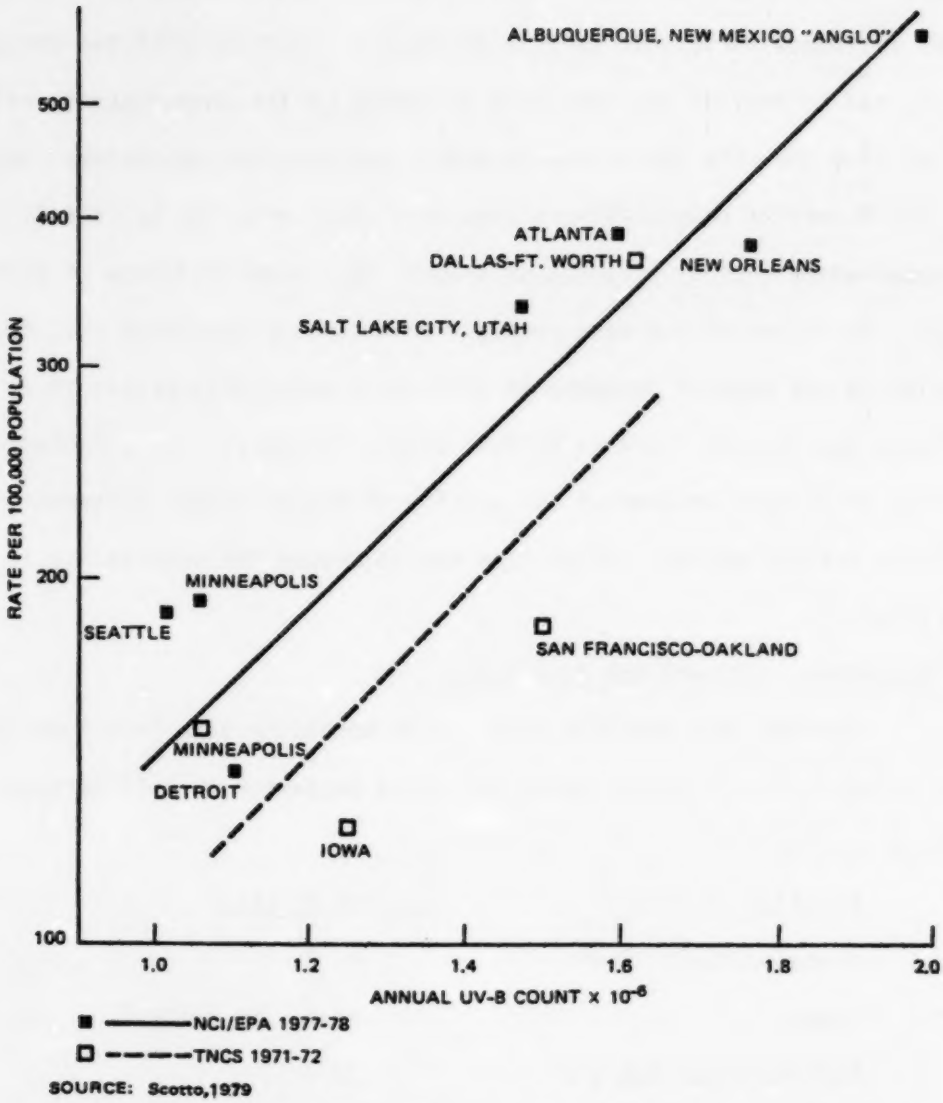
- The point prevalence rate (number of cases per unit population at a point in time). These are available for many locations --principally through the Health and Nutrition Examination Survey (HANES)--but the numbers for melanoma are quite small.

- Mortality rates (number of deaths per unit population per unit time). These rates have been available for the entire country for over 45 years, but most of the published sources do not have separate mortality rates for melanoma and non-melanoma skin cancer. Mason and McKay (1974) have published age-adjusted mortality rates for each of these cancers for each county for the years 1950 through 1969 combined. They conclude that both sexes show a "striking southern predominance extending from coast to coast."

For a determination of the economic impact, incidence rates would be the most useful response measure. For melanoma, the incidence rate offers a good approximation of this response measure because it is unusual for an individual to develop two independent melanomas in his lifetime. However, occurrences of non-melanoma skin cancer in the same individual are relatively common. So for this disease, the response measure would have to be calculated directly.

b. NCI Skin Cancer Study

EPA provided funds to the National Cancer Institute in support



SOURCE: Scotto,1979

Figure 2. Nonmelanoma skin cancer incidence in the United States by UV-B exposure as calculated by Scotto.

Adjusted for New Mexico "Anglos"

of research directed at estimating the human health effects of stratospheric ozone depletion. Specifically, the NCI was asked to conduct skin cancer incidence surveys in various geographic locations with the United States, and to provide more reliable estimates of the dose-response relationship of UV-B and skin cancer development among American Caucasians. Results from NCI's earlier investigations were consistent with the hypothesis that increased amounts of UV-B radiation lead to increased incidence of skin cancer. Estimates of the dose-response relationship indicated that for most locations a one percent increase in UV-B would eventually result in an approximate two percent increase in skin cancer incidence. This factor of two had been challenged because of the paucity of epidemiologic information available for evaluation. NCI's task was to reduce the uncertainty in this estimate.

Materials - Old and New Data Bases

Earlier, NCI provided skin cancer morbidity data from four locations (covering a six-month survey period of September 1, 1971 through February 28, 1972).

Location	Degrees N. Lat.
Minneapolis-St. Paul	44.9
Iowa	42.5 (Des Moines)
San Francisco-Oakland	37.8
Dallas-Ft. Worth	32.8

Currently, eight population-based incidence surveys have been conducted (covering a 12-month survey period of June 1, 1977 through May 31, 1978).

	Location	Contractor	Degrees N. Lat.
Northern Latitudes	Seattle (King Co.)	Fred Hutchinson Cancer Research Center	47.5
	Minneapolis-St. Paul	University of Minnesota	44.9
	Detroit	Michigan Cancer Foundation	42.2
Middle Latitudes	Utah	Utah Cancer Registry	40.7 (Salt Lake City)
	San Francisco-Oakland	California Tumor Registry	37.8
Southern Latitudes	New Mexico	New Mexico Tumor Registry	35.1 (Albuquerque)
	Atlanta	Emory University	33.7
	New Orleans	Tulane University	30.0

All but one location (Minneapolis-St. Paul) in the new survey belong to NCI's main cancer (SEER) program. Attaching this special study to the SEER Program quickly assured the best available, active cancer registry program on a national level. Morbidity from other malignancies could also be measured and compared directly with non-melanoma skin cancer incidence in these locations. For the short-term effort, this cancer reporting network provided immediate access to physicians and other sources seeing and treating skin cancers.

The new locations span 17.5 degrees north latitude and a UV-B ratio of 2:1 from south to north. Two locations, San Francisco and Minneapolis, will provide bases for establishing trends in incidence. In collaboration with Census Bureau demographers, population estimates were derived specifically for each location for December 1, 1977, the midpoint of the latest survey period. Better population estimates will be available after the 1980 census.

It is recognized that the solar ultraviolet measurement is not the only factor to consider in evaluating variations in skin cancer incidence among population groups. Specifically, to what degree do host (e.g., genetic) factors or environmental factors influence the development of disease? Racial groups, such as Blacks and Orientals, and ethnic groups, such as Hispanics are rarely, if ever, affected by this disease. Environmental exposures other than solar UV-B, (e.g., ionizing radiation, oils, coal tar, industrial chemicals, etc.) have been associated with the development of this disease. In this report, we are adjusting only for the ethnic group known as "Anglos", i.e., Caucasians other than Latin, in Albuquerque, New Mexico. At a later date we will incorporate epidemiological data, relative to outdoor exposure, ethnicity, industrial exposures, ability to tan/sunburn, etc., into the analytical models.

Results

Table 1 shows the latest information on annual UV-B insolation and the age-adjusted non-melanoma incidence rates for Caucasians. It is clear that populations with high possible exposures to UV-B also have high levels of skin cancer development. Figure 3 shows these points. The data are plotted on a semi-log scale so that a straight line with a positive slope represents a constant percentage increase in responses.

Assuming that annual UV-B flux increases by one percent at each location, and applying the results of this model to the new data bases, estimates of the relative effects on non-melanoma incidences were calculated (Table 2). The model implies that Caucasians residing in areas of high UV-B exposure may be most affected. Thus in a northern location, such as Detroit, a 1% increase in UV-B may result in a 1.4% increase in skin cancer incidence,

Table 1

UV-B INSOLATION AND THE AGE-ADJUSTED SKIN CANCER INCIDENCE RATES FOR CAUCASIANS

Location	Annual* UV-B Count x 10^{-4}	Skin Cancer Incidence Rates Among Caucasians Age Adjusted (1970 US)/100,000/Yr. 1977-78	(S.E.)	1971-72	(S.E.)
Seattle	101	188.7	(4.0)		
Minneapolis	106	193.3	(3.3)	150.9	(4.3)
Detroit	110	135.6	(2.0)		
Iowa	125			123.7	(2.7)
Salt Lake City	147	299.3	(6.5)		
San Francisco	151	213.0	(2.6)	183.6	(3.6)
Atlanta	160	393.8	(6.1)		
Dallas	161			379.3	(6.6)
New Orleans	176	384.2	(7.1)		
Albuquerque (Anglo)	197	504.1	(14.9)		

*The annual UV-B counts are from preliminary monthly averages provided by Daniel Berger of Temple University. NOAA will soon provide the detailed, hopefully, final counts for 1977 and 1978.

Note: S.E. refers to the Standard Error of the given incidence rate, per 100,000 population.

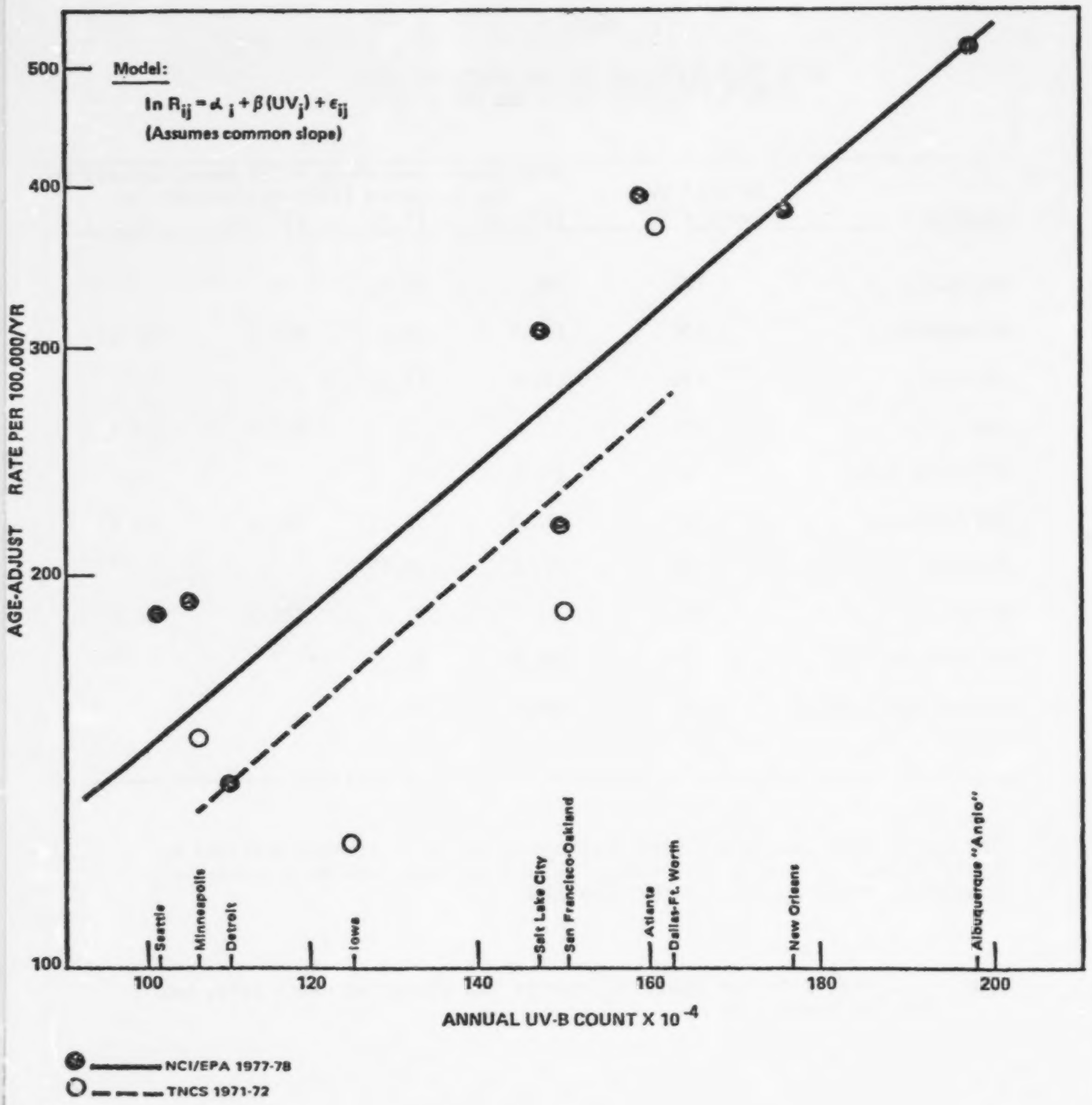


FIGURE 3 NONMELANOMA SKIN CANCER INCIDENCE IN THE UNITED STATES BY UV-B EXPOSURE (ANNUAL UV-B COUNT X 10^{-4})

Table 2

ESTIMATED RELATIVE INCREASE IN SKIN CANCER INCIDENCE
ASSOCIATED WITH A 1% INCREASE IN UV-B BY GEOGRAPHIC LOCATION

Location	Annual UV-B Count x 10^{-4}	Lower Limit	Estimated % Increase	Upper Limit
Seattle	101	0.63527	1.31590	2.00114
Minneapolis	106	0.66682	1.38149	2.10124
Detroit	110	0.69207	1.43400	2.18139
Iowa	125	0.78682	1.63113	2.48252
Salt Lake City	147	0.92593	1.92095	2.92578
San Francisco	151	0.95125	1.97373	3.00657
Atlanta	160	1.00823	2.09260	3.18860
Dallas	161	1.01456	2.10581	3.20885
New Orleans	176	1.10961	2.30425	3.51300
Albuquerque (Anglo)	197	1.24283	2.58271	3.94032

while in a southern location, such as Atlanta, the relative increase in skin cancer may be greater than 2%.

While these point estimates are slightly smaller than those derived using only the four locations of the earlier NCI survey, the degree of reliability has indeed improved. As an example, the point estimates and confidence intervals for Iowa and Dallas-Ft. Worth are:

	Iowa (42.5° N. Lat.)		Dallas-Ft. Worth (32.8° N.Lat.)	
	4 Area Survey Only	New Data Bases (10 Areas)	4 Area Survey Only	New Data Bases (10 Areas)
Percent change in Incidence for 1% Increase in UV-B	2.35	1.63	3.05	2.11
95% Confidence Interval	-2.78 to 7.77	.78 to 2.48	-3.57 to 10.12	1.01 to 3.21

Finally, it should be noted that more locations, in both northern and southern zones, are needed to further refine the dose-response estimates. It is hoped that the additional epidemiologic data from the sample survey, when incorporated into the analyses of the new data bases, will further clarify the role and importance of host factors and environmental factors other than solar ultraviolet.

c. Melanoma of the Skin

The age-adjusted death rates from melanoma have increased from 1951 to 1975 by about 3% per year in the population of England, Wales, and Canada, and the white population of the United States. Lee, et al. (in press) have shown that this increase is due to the large increases in risk because of changing social customs of exposing more of the body with successively later years of birth (birth cohorts).

Apparently any effects of earlier diagnosis or improved treatment within the period 1951-1975 have not been sufficient to alter these trends. Lee, et al. calculated the projected course of future mortality rates of malignant melanoma (Table 3). While these projections are not explicitly exposure dependent, they provide a basis for projecting future melanoma mortalities assuming future changes in UV intensity, life styles and other factors are consistent with past changes.

Green (1978) evaluated the age-exposure equations developed by Fears, et al. (1977) to determine if reciprocity holds for melanoma and non-melanoma incidence rates. The property of reciprocity implies that the cumulative risk to a homogeneous population of equal age can be expressed as a product of age (i.e. time of exposure) times UV flux. This property is important both in the establishment of dose-response relationships and in the evaluation of potential effects of increased UV exposure. Green suggests that reciprocity may be valid in the case of melanoma, but violated for non-melanoma. Other experimental data indicate that reciprocity does hold for non-melanoma. Moreover, the results suggest that the greater occurrence of non-melanoma in the older population is not just the result of accumulated UV doses, but that aging itself and UV radiation may be synergistic; alternatively, this greater occurrence could be due to a birth cohort effect, or combination of the above effects.

All dose-response methods provide in some way for UV, sex, and age, and are estimated for the "white" population only. A number of other factors may be, and in some cases have been, included. Scott and Straf (1977) report trying solar radiation, urbanicity, microclimate, proportion of white population that is fair-skinned, access to medical care, economic level of the locality, and access to melanoma clinics.

Table 3

DEATH RATES AND PROJECTED DEATH RATES
FROM MALIGNANT MELANOMA OF SKIN
BY SEX AND TIME PERIOD

Time Period	U.S. White Population	
	Males	Females
1951–1955	14.5	11.2
1956–1960	16.6	12.6
1961–1965	19.9	13.8
1966–1970	22.9	15.4
1971–1975	26.3	16.5
1976–1980*	28.7	17.7
1981–1985*	33.5	18.8

Source: Lee et al. (in press).

Note: Rates are given per million per year, age-adjusted using the UICC standard European Population.

*Projected values.

They conclude that temperature and pigmentation play a role in skin cancer, but that UV flux is the most important factor. In an analysis of skin cancer and solar keratosis data from Queensland, Australia, Silverston and Searle (1970) found susceptibility to sunburn to be an important prediction variable. Other variables evaluated were sex, age, complexion, eye color, ancestry, occupation, clothing habits, and residential district. More recently, Vitaliano (1978) used logistic regression to estimate the relative risk of U.S. basal and squamous cell carcinoma for such factors as cumulative lifetime solar exposure, age, complexion, and tannability. A linear effect for the relative risk of cancer versus exposure was found. Tannability was shown to be a more important risk factor than complexion.

d. Case Control Studies

The National Cancer Institute and the Massachusetts General Hospital are each conducting a case control study quantifying skin cancer risk for individuals with different physical characteristics and life styles. The NCI investigators are selecting a systematic sample of their series of incident cases and a random sample of the general population for non-melanoma skin cancer (Scotto and Fears, 1978). In a separate study, the Massachusetts General Hospital group is studying newly-diagnosed melanoma patients and their best friends of this age who are living in the same neighborhood.

Both case control studies rely on questionnaires to obtain information on physical characteristics and sunlight exposure for each subject. While the questionnaires for the two studies differ, similar items of information are being ascertained for both. These include history of time spent outdoors at different times during the subject's life, hair and

eye color, history of skin conditions, occupational history, ethnicity, skin color, and ability to tan. Appropriate analysis to reflect the months of data collection has not yet been carried out by NCI and the Massachusetts General Hospital investigators, so their study findings are also not available at the time of this report.

3. In Table 4 we briefly summarize research areas in need of further effort in order to refine the relationship between skin cancers and ultraviolet radiation. In this table, we distinguish between short and long-term programs. Short-term programs are those that will return substantial quantitative knowledge within a 2 to 3 year period and are required as a scientific basis for regulatory decisions. Long-term research is needed in order to broaden the base of knowledge and further reduce the uncertainties in order to refine the scientific basis for regulatory decisions.

The first three short-term items in Table 4 consist of continuations of current research. The third item identifies a research need to provide better linkage information between ultraviolet exposure and the risk of disease. Long-term epidemiologic studies which use direct measures of ultraviolet exposures (i.e. dosimeters) are required if we are to refine the relationship between skin cancer and ultraviolet. Finally, studies on nonhuman systems are needed to provide knowledge concerning the mechanisms of skin cancer induction.

Table 4

HUMAN HEALTH RESEARCH NEEDS

Need	Research Method and Purpose	Benefits
Epidemiological data analysis	Continue the analysis of existing morbidity and mortality data to quantify the relationship between ozone depletion and skin cancer.	Short-term
UV Radiation monitoring	Continue the Robertson-Berger network at key epidemiological locations. Correlate data with epidemiological effects and dosage measurements.	Short-term
Personal dosimeters	Develop, test, and deploy personal dosimeters. Correlate data with other indicators of personal dose (i.e., questionnaires, latitude, and Robertson-Berger measurements).	Short-term
Data on nonmelanoma skin cancer	Collect data in order to calculate incidence rates for nonmelanoma skin cancer in defined geographic areas.	Long-term
Identify high-risk groups	Determine the effect of other factors and calculate risk of specific exposures by conducting case-control and other epidemiologic studies of both melanoma and non-melanoma skin cancer.	Long-term
Animal and cellular research	Conduct studies to acquire basic information on the mechanism of skin cancer induction.	Long-term

B. Nonhuman Biological Systems

1. Background

Data collected under the SIRA program give cause for concern with respect to losses in fisheries and many crops. There is also a largely unexplored potential for adverse interactions with pathogens, pollutants, and drought.

The potential for losses in oceanic fisheries lies both in the adverse effects of UV-B on the survival of larvae of the fisheries themselves and in the adverse effects of UV-B on the invertebrates upon which these fish feed. Too few fish and invertebrate species have been examined to reliably assess the potential losses which can be expected. Some fish and invertebrate species of commercial significance suffered 50% or greater increases in mortality when exposed to a 40% increase in the DNA-weighted intensity of UV in the laboratory (Hunter et al., 1979). This can be argued to be a "worst case" estimate given the uncertainties in the number of species which will be this sensitive, the degree to which the mortality increases will be offset by more rapid growth of the survivors, the extent to which significant segments of the population will be sheltered by remaining sufficiently far below the surface, and the extent to which resistant species can substitute for sensitive species. Nonetheless, these data are cause for significant concern.

Studies of effects on mammals other than man have been limited to research on an eye disease in cattle known as cancer eye (ocular squamous cell carcinoma). Analyses of latitudinal gradients in the prevalence of cancer eye are suggestive of a causal tie to sunlight intensity, but this has not been demonstrated. Unquestionably, the percentage of cattle rejected at

the slaughter houses due to the occurrence of cancer eye has doubled over the past twenty-five years (Kopecky, et al., 1978). However, this may reflect changes in inspection standards, or possibly unknown factors of recent introduction.

Lack of pigmentation concurrent with the absence of hair, feathers or scales (and hence exposure to highly sensitive surfaces) appear to be limited to man, his domesticated animals, and juvenile organisms not normally exposed to sunlight. Therefore, it is unlikely that skin cancers or cancer eye will be common in wild animals.

Field studies of the sensitivity of crop plants have been inconclusive, but roughly half of the 82 crops examined in a major survey using controlled environments in the laboratory suffered at least a 5 to 25% reduction in growth when exposed to UV-B (Briggs and Kossuth, 1978). An additional fourth suffered more than 50% growth reductions. These laboratory results overestimate the impact of UV-B in the field where adaptability mechanisms, not yet identified, reduce the impact of UV-B.

Impacts on noncrop plants have received little attention. The data obtained for tree and shrub seedlings of commercial significance suggest that these species will tend to be relatively resistant, but these data must be used with caution (Kaufmann, 1978). They are based on very brief observations and it is quite possible that expression of effects will be delayed in some of these plants. Moreover, effects may be marked by the naturally occurring variations among individual plants. In brief experiments with such slowly growing species and small sample

sizes, considerable periods may be required for changes in growth rates due to UV-B irradiation to be demonstrable.

Interactions among pathogens and crops were partially examined in the first year of the SIRA program, but the potential significance of such interactions is still unclear. Initial experiments showed some significant reductions in the incidence and severity of diseases, at very high UV-B intensities (Carns, et al., 1979).

2. Current Research

a. Marine Organisms

Research, during the latest biennial period of the SIRA program, emphasized the marked impacts on marine foodchains which were noted in the first year's research. The three programs funded in 1978 and 1979 focused on the potential risks to marine fisheries: a study of the effects of UV-B on anchovy and mackerel larvae; a study of effects of UV-B on crabs, shrimp, and other invertebrates; and an assessment of the penetration of ocean waters by UV-B. These studies, and a closely related study of the effects of UV-B on zooplankton, funded by NASA, cover representative species of commercial significance, the food chains sustaining these commercial species, and the potential for exposure of organisms as a function of the depth and the water types.

The fisheries studies, conducted by J. R. Hunter at Scripps, focused upon the Pacific mackerel and the northern anchovy, species whose larval forms are respectively restricted to the surface waters of the ocean

and distributed throughout the upper, mixed layer of the ocean. Of the two, the anchovy, which is unpigmented and is found over a depth range associated with considerable variation in the intensity of UV-B, is the more sensitive. Existing UV-B intensities (105 J m^{-2}, DNA-weighted) represent about twice those required to either significantly retard growth after 12 days exposure (44 J m^{-2}) or cause 50% mortality (56 J m^{-2}). Laboratory experiments indicate that exposure of anchovy larvae to UV-B levels which would follow a 13-25% reduction in the ozone layer (141-190 J m^{-2}) would kill almost all of the larvae after 12 days, reducing survival by roughly half relative to present levels (Hunter and Taylor, 1978). However, these estimates of mortality are conservative since many of the anchovy survivors appear to have suffered brain damage which impaired the ability of the larvae to feed. Thus, many of the survivors might not survive to sexual maturity even if exposed to no more UV-B. In addition to increased probability of starvation, these slowly growing survivors would be more vulnerable to predators due to the delayed growth, which for fishes generally also means a delay in the age of first reproduction. This demographic parameter influences the birth rate of the population perhaps more than any other parameters.

While implications of Hunter's data are gloomy, they are tempered by the fact that some fraction of the anchovy population exists at sufficient oceanic depths to be protected from enhanced UV-B. Although the size of this fraction is unknown, the fact that the anchovy larvae are very sensitive to current levels of UV-B and lack protective pigments suggest that

the fraction which is unexposed is substantial. Thus, the prognosis based on effects on the fish themselves is unclear. The effects are strong enough to warrant great concern and further study, but the chief uncertainty lies in the estimation of the dose which these species will receive, not in the estimation of the consequences of a given dose.

Experiments with individual commercially important species of crabs and shrimp and with food chains supporting marine fisheries, essentially parallel the fish experiments (Damkaer, et al., 1978). The current levels of UV-B radiation are harmful near the end of the normal period of larval development and may indeed be a significant factor in determining the seasonalty of development. A 20% reduction in stratospheric ozone concentrations, representing an increase of about 40% UV-B, would definitely reduce the length of the period favorable to larval development; it is not clear that commercially significant populations would survive with these drastically shortened periods for reproduction. Responses of important invertebrates within oceanic foodchains which sustain commercial fisheries respond similarly (Damkaer, et al., 1978), and freshwater phytoplankton exhibit statistically significant reductions in productivity, chlorophyll content, and species composition after five weeks exposure to current levels of UV-B radiance when compared with unirradiated controls (Van Dyke and Worrest, 1978). As in other experiments, it is difficult to elicit quantitative predictions from the researchers, although there is agreement that the data are sufficient to warrant concern.

b. Terrestrial Plants

Studies by Caldwell (1979) at Utah State University--partially supported by the SIRA program--explored mechanisms by which

ultraviolet radiation affects higher plants and the degree to which plants might be able to adapt to increased UV radiation. These studies included measurement of biologically effective solar UV-B radiation over a natural latitudinal gradient from the Andes to Alaska and assessment of plant optical properties along this gradient. This study showed that plants growing in naturally high UV radiation environments (environments in which the UV flux is already higher than that anticipated to occur at temperate latitudes if ozone reduction occurs) possess effective screening mechanisms by which the potentially damaging UV radiation is largely shielded from reaching the internal parts of a leaf. This does not suggest that all species of plants will be able to adapt in this manner, nor does it mean that species growing in tropical latitudes under a naturally high UV radiation environment could adapt to still higher intensities. Nevertheless, the fact that many plants can exist in naturally more intense than average UV radiation environments, including many that were previously taken from temperate latitudes, does complicate the assessment of potential consequences of ozone reduction on land vegetation.

Several physiological mechanisms by which ultraviolet radiation can affect plants have been investigated recently in the laboratory of Caldwell. These included studies of the effects of this radiation on the plant phytochrome system, certain plant hormones, and how this radiation stress can interact with other common stresses in the plant environment such as mild water stress or the stress of competition with other plants. Many stress interactions have become apparent in this research. These studies again demonstrate the complex nature of assessing consequences of ozone layer reduction on plants in both agricultural and wild land systems.

Studies of the basic mechanisms may, however, help to eliminate the need for extensive screening programs that are both costly and extremely time-consuming.

3. Projections and Uncertainties

Estimated effects of ozone depletion on nonhuman systems cannot be summarized in a concise way because of the numerous types of species involved and their particular sensitivities to UV-B radiation. Research has been performed on only a limited number considered important economically. As stated in Section III.B.1, research has been conducted on about eighty varieties of land plants, several types of fish, but only a few nonhuman animals (primarily cancer eye in cattle). (It should be noted, however, that hairless mice are used effectively to study the production of skin cancers by UV-B radiation.) Therefore, our approach to summarizing this research is restricted to the particular species involved.

a. Effects of UV-B on Marine Organisms

Based on the literature and direct communications with researchers concerning their laboratory experiments, we prepared a summary table (Table 5) projecting the loss of productivity due to increased UV-B exposure for several aquatic organisms. Losses of productivity in commercial fisheries could result from (1) increased UV-B exposures on the sensitive species and (2) increased UV-B exposures on organisms (e.g., algae) fundamental to the oceanic food chain. Hence, the first item in Table 5--algae--is potentially significant because many commercial fisheries depend on algae, the ultimate source of food of most oceanic animals. Hence, a loss of algae productivity would be reflected in losses in commercial fisheries even though these losses might be difficult to

Table 5

LOSSES IN AQUATIC ORGANISMS

Species	Excess Mortality (%)	Increase in UV-B Exposure DNA-Weighted (%)	Data Source
Algae (diatoms)	4	38	Van Dyke & Worrest, 1977
Shrimp (pandalus species)	50	57	Damkaer et al., 1978
Dungeness crab	50	56	Damkaer et al., 1978
Crab (cancer oregonensis)	50	41	Damkaer et al., 1978
Anchovy	80	26	Hunter et al., 1978
	99	50	Hunter et al., 1978
Mackerel	10	26	Hunter et al., 1978
	80	50	Hunter et al., 1978
Freshwater microinvertebrates*	50	>50	Calkins, 1975

*Probable maximum estimate of mortality.

quantify or even demonstrate outside the controlled environment of a laboratory. (Analysis of actual field conditions is complicated by other variables such as changes in fisheries practices and the large year-to-year variations that occasionally characterize oceanic fisheries.)

Several commercial species tested appear to be more sensitive than algae to increased UV-B dosages (see Table 5). Therefore, UV-B effects would be expected to manifest themselves first in the form of shifts in the prevalence of UV-B sensitive and UV-B resistant species in the commercial catch. Losses in the productivity of oceanic fisheries in total due to losses in the productivity of the algae would occur later.

b. Cancer Eye in Cattle

A causal relationship between UV-B and cancer eye has not been proven. Hence, attempts to project increases in cancer eye would be premature.

c. Terrestrial Plants

Direct Effects of Increased UV-B

Effects on terrestrial plants in the greenhouse and in growth chambers are very strong, but have not been verified under field conditions. This could reflect either the presence of effective repair mechanisms, or some unknown interaction between plants, UV-B, and visible light at high light intensities, or difficulties of obtaining statistically reliable data under field conditions.

Effects considered significant may occur in the presence of enhanced UV-B in the field, but generally this has not been proven. Laboratory data indicate that a 40 percent increase in UV-B might cause a 10 to 20 percent loss in the yield of many commercial species. However, the

associated with these projections are quite large (100 percent or more). The cognizant scientific community as a whole is unwilling to venture projections of what could happen to commercial species under field conditions, given enhanced UV-B. They maintain that long-term (3-year minimum) field studies, including studies of adaptability mechanisms, are needed before making any projections.

Secondary Effects Due to Climate Changes

As described in Section III.C., UV-B enhancement may have a direct impact on climate. However, in view of the many unknowns, reasonable estimates for climate changes exist only for one parameter--global average temperature.

The estimated magnitude of the global temperature change and problems associated with estimating other agriculturally significant changes (e.g., precipitation and regionality) are also discussed in Section III.C.

4. Future Needs

The data base for assessment of the impacts of stratospheric ozone depletion on nonhuman biological systems is sufficiently extensive to warrant concern, but they are insufficient to allow definitive assessments. Assessments of the impact on either marine or terrestrial species of little commercial significance or on total ecosystems are even more constrained. A series of studies with modest but sustained funding, as is currently going on in the laboratory, needs to be continued under field conditions to appraise the probability that sensitive organisms exposed to UV-B will have the ability to tolerate the increased UV-B received (Table 6).

Analyses of light penetration, depth distributions, and avoidance behavior are needed to reduce the large uncertainties involved in use of

Table 6

NONHUMAN BIOLOGICAL RESEARCH NEEDS

Research Need	Specific Research Area	Benefit
Penetration of light in natural waters		Short-term
Depth distributions of larval forms of marine fishes		Short-term
Fisheries	Extend the assessments of the sensitivity of commercially significant fish species.	Short-term
Photorepair	Extend analyses of the interaction between UV-B and photorepair to field experiments to facilitate the extrapolation of existing growth-chamber and greenhouse data to field conditions	Short-term
Interactions among species	Replicate and expand experimental studies of the effects of UV-B on interactions between plants, animals, and microbial pathogens or symbionts in both terrestrial and aquatic experiments.	Long-term
Behavioral responses	Examine the effects of UV-B on animal behaviors particularly the ability of fishes to avoid exposure and the pollination of crops by bees.	Long-term
Woody plants	Extend the analyses of the sensitivity of tree and shrub seedlings to multiyear studies of species of commercial significance.	Long-term
Hydrocarbon releases from plants		Short-term

the data on commercially important fishes. We are relatively ignorant of the vertical distribution, and hence exposure, of many of these species, although several are known to spend several weeks within one meter of the surface during early development. We lack data on their ability to detect and avoid UV-B, and very few species have been examined relative to wide range of sensitivity. Hence, while it is clear that though some commercially important fisheries may be very severely affected, we lack sufficient data to safely predict the sensitivity of species other than those examined.

The data base for noncommercial species of land plants is also weak and should be explored by means of multi-year studies. It is possible that timber production may be more sensitive to increased UV-B than only as a question of seedling survival. Although we lack data to substantiate this hypothesis, there remains need both for further study of the action spectra for photoeffects and for study of the mechanisms of photoactivated repair. An understanding of the action mechanisms spectra and repair would greatly facilitate extrapolation from greenhouse and laboratory studies to the natural environment, and expedite extrapolation to unstudied species.

C. Climate Effects

1. Background

One possible effect of ozone depletion is climate modification. The source of such climatic modification is a change in the atmospheric transfer of radiant energy. Ozone strongly affects this transfer in several regions of the solar and terrestrial radiation spectra, and hence changes in the amount and vertical distribution of ozone (as shown in Figure 4) can alter atmospheric temperature, both near the earth's surface and throughout the vertical. In turn, these temperature changes might lead to perturbations of current weather patterns and to local changes in precipitation and temperature.

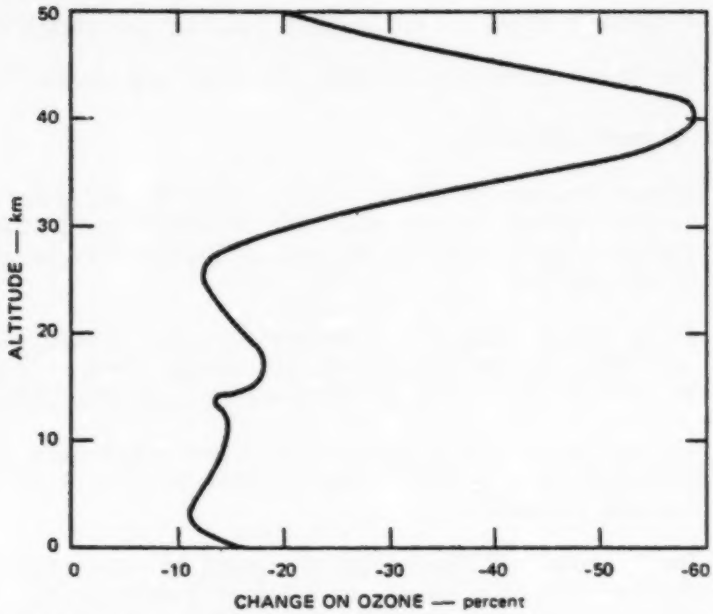
It is important to recognize that CFC's themselves, before photodissociation in the stratosphere, also affect atmospheric radiation and that these effects will combine with any radiative effects of ozone depletion. In particular, both CFC-11 and CFC-12 absorb strongly in parts of the terrestrial radiation spectra. Thus, these gases reduce the escape of terrestrial radiation from the earth (creating a so-called greenhouse effect) and tend to warm the earth's surface. This direct radiative effect of CFC's must be considered, along with ozone-depletion radiative effects, in making a complete assessment of CFC impacts on climate.

2. Recent Research

Nearly all recent and current research on the climatic effects of ozone depletion and of ozone-depleting substances has focused on temperature changes. Much less work has been done on the resulting changes in circulation and precipitation, although these aspects should be understood if the full impact of climatic change is to be evaluated.

a. Mechanisms that Affect Climate Change

Over longtime scales (one year or greater), the earth-atmosphere system maintains radiative equilibrium. Changes in atmospheric



SOURCE: Logan, et al. (1978)

Figure 4. Vertical profile of ozone depletion by CFCs predicted by a one-dimensional photochemical model.

One-dimensional photochemical models describing tropospheric ozone depletion are more uncertain than similar models describing stratospheric ozone, because the tropospheric NO_x levels, which critically control production, are highly uncertain.

composition (e.g., carbon dioxide increase, CFC increase, ozone depletion) that alter the earth's radiative energy budget should be expected to cause climate changes. It is emphasized that CFC releases are only one of many possible causes of climate change, the dominant cause being carbon dioxide increases due to fossil fuel combustion, and deforestation. Accurate quantification of these changes is not viable because our knowledge is inadequate. However, some characteristics of the mechanism are known. These characteristics are summarized below:

- Direct effects of CFC's, carbon dioxide and other greenhouse causing gases and aerosols are expected to be monotonic but the magnitude of their effect will generally be amplified in polar regions.

- Ozone composition has a natural seasonal cycle and varies with latitude. Hence changes in its composition will not necessarily be uniform with time or altitude or over the globe.

- The response of the earth-cryosphere-ocean system to radiative perturbations is still largely unknown and is at the core of present research.

- The response of the system is bound to cause further anomalies in the radiation budget that would give rise to additional response, e.g. changes in hydrologic cycle due to circulation changes would affect radiation budget through changes in H_2O vapor and cloud cover. (See Schneider and Dickinson, 1974).

- Changes in surface albedo from melting of ice or from UV-B induced changes in plant growth can also produce changes in the radiative budget.

- Additional anthropogenic changes--for example, released CO_2 in burning of fossil fuels--will cause heating of the troposphere and cooling of the stratosphere. The latter will in turn lead to less O_3 depletion. The reduction, however, is rather small.

- Other anthropogenic sources of greenhouse-causing gases and aerosols may also intensify or inhibit the net radiative effects produced by the CFC's. (See Wang, et al., 1976).

Climate change is also difficult to assess because the system

may be intransitive, i.e., it may exhibit more than a single ensemble of states (ice ages, interglacials) with no apparent changes in external boundary conditions (solar constant atmospheric composition). (See Schneider and Dickinson, 1974; Hartmann and Short, 1979). Multiple states have also been obtained in solutions to photochemical models.

Thus, even though the perturbation to the radiative energy budget might be readily characterized, the response of the climate system is unforeseeable (e.g., radiatively, a doubling of CO_2 should cause a warming of the lower troposphere, but it remains highly speculative how much warming occurs at a particular time and place).

b. Mathematical Models

There are a number of different types of models which potentially can be used to assess climate changes. However, these models are not developed to the point where they can adequately predict climate changes due to CFC emissions. Research to develop and improve climate models is the primary thrust of the National Climate Research Program under the aegis of the National Oceanography and Atmospheric Administration.

3. Projections and Uncertainties

Temperature Changes

The development of climate models have begun to result in a better understanding of tropospheric radiative energy budget and the response of surface temperature to CFC induced radiative changes. The most recent understanding of the impact of CFC releases on surface temperature is illustrated by calculations performed by Ramanathan (Ramanathan and

Dickinson, 1979) of the National Center for Atmospheric Research. It is assumed that if the CFC emissions for CF_2Cl_2 and $CFCl_3$ continue at their 1975 level and with steady state conditions in the atmosphere of 1 ppb for CF_2Cl_2 and 2 ppb for $CFCl_3$, then the global average surface temperature will increase by 0.4^oC. This compares with an estimated 2 - 3^oC increase for a doubling of atmospheric concentrations of CO_2.

4. Future Needs

Climate research is now the responsibility of the National Climate Program Office within NOAA. Therefore, most of the needs, listed in Table 7, should be conducted within the framework of the National Climate Program.

Table 7

CLIMATE RESEARCH NEEDS

Research Need	Method	Benefits
Climate workshop	Organize and convene workshop on anthropogenic climate modification. Invite national and international experts in the field of climate modeling and monitoring. Assess the state of the art of potential global and regional climatic impact of anthropogenic atmospheric perturbations, such as ozone depletion, increasing burden of infrared absorbing species (CFC, CO_2, N_2O, H_2O), and aerosol particles.	Short-term
Statistical analyses	Apply judicious statistical methods to existing climatological data, both to detect possible anthropogenic trends in climate variables and ozone and to design better monitoring systems.	Short-term
Climate models	Assess by means of theoretical modeling, using an empirical data base, the climatic changes that may occur as a consequence of anthropogenic activity. The primary concern will be the alteration to the radiation budget by ozone removal, aerosol formation, and introduction into the atmosphere of other infrared absorbing/emitting species. Include latitude dependence and feedback by ice albedo and clouds.	Long-term
Trace substance monitoring	Monitor atmospheric trace substances (including aerosols) that play a central role in determining anthropogenic influence on climate.	Long-term
General circulation models	Improve general circulation models to simulate the effects of ozone-depletion-induced changes in tropospheric temperature, stratospheric temperature, and winds on planetary waves and storm tracks. Improve cloud parameterization to permit inclusion of cloud-feedback effects.	Long-term

IV FEDERAL AND INTERNATIONAL RESEARCH COORDINATION

A. Interagency Committee on Stratospheric Ozone Protection

The Interagency Committee on Stratospheric Ozone Protection (ICSOP), in accordance with Section 150 of the Clean Air Act Amendments of 1977, has been functioning under the chairmanship of EPA. Membership includes: Department of Agriculture, Department of Defense, National Institutes of Health, Food and Drug Administration, Department of Commerce, National Bureau of Standards, National Aeronautics and Space Administration, National Science Foundation, Consumer Product Safety Commission, National Institute of Environmental Health Sciences, Federal Aviation Administration, and the National Oceanic and Atmospheric Administration.

Early in 1979 the ICSOP, in order to identify research needs and gaps, formed three subcommittees: Atmospheric Sciences, Health Effects, and Biological and Ecological Effects. The Atmospheric Sciences subcommittee was chaired by the National Oceanic and Atmospheric Administration, the Health Effects subcommittee by The Department of Health, Education and Welfare, specifically the National Cancer Institute, and the Biological and Ecological Effects subcommittee by the National Science Foundation. Reports were submitted by the subcommittees in September 1979 and are being used to guide the individual agencies involved in accordance with their research capabilities and interests. EPA has requested the National Academy of Sciences, in light of their expertise and recent reports on stratospheric ozone, to evaluate the ICSOP subcommittee reports and provide their research recommendations.

B. United Nations Environment Program/Coordinating Committee on the Ozone Layer

The United States is an active member of the United Nations Environment Program/Coordinating Committee on the Ozone Layer (UNEP/CCOL), which has as its purpose the integration, evaluation, and dissemination of research results on causes and effects of stratospheric ozone depletion. Participants are: the nations that are major user/manufacturers of CFC's, e.g. the United States, Canada, the United Kingdom, France, Norway, Sweden, the Netherlands, Italy, West Germany, the USSR, Australia, and occasionally other nations; involved international scientific organizations, e.g. World Meteorological Organization (WMO), World Health Organization (WHO), and the International Council of Scientific Unions (ICSU); and industry, e.g. Chemical Manufacturers Association (CMA).

The most recent annual meeting of the CCOL was held in Paris, France, November 20 - 23, 1979. A report of that meeting will be published by UNEP in several months. Its principal conclusions, developed by all participants, are in excellent agreement with the recent NAS findings (discussed in Section II) and are summarized as follows:

- The UNEP Committee on the Ozone Layer met in Paris from 20 - 23 November for its third session. The Committee examined the substantial contributions presented to it by various countries, and the research efforts in measuring and modelling necessary for the study of the stratosphere. Having considered the new information available from countries and international bodies, including comprehensive new reports of the National Academy of Sciences of the USA and of the Department of the Environment of the UK, its present assessment remains broadly similar to that made by the UNEP Committee in November 1978.

- The Committee concluded that a risk to the ozone layer is still most likely due to chlorofluoromethane releases, although in the future other components, such as methylchloroform, which can reach the stratosphere, require increased consideration.

- Present model calculations are estimated to result in an ultimate ozone depletion of about 15 percent, if chlorofluoromethane releases continue at the present rate. According to these models an ozone depletion of about 2 percent should already have occurred. Such an amount cannot be detected directly with present technology, and no change attributable to human activity has been observed.

- The influence of NO_x (from supersonic aircraft) and of N_2O (from fertilizers) seems to be of minor importance.

- For many species, there is an acceptable agreement within the range of uncertainties between model calculations and atmospheric measurements. In some cases, however, discrepancies occur that cannot yet be explained.

- There is increasing, but still inadequate knowledge of possible effects of increased UV-radiation on ecosystems and plants, which may be the most serious impact. There is a high degree of correlation for the relationship between UV-B radiation and non-melanoma skin cancer in man, and there is some indication that there may be a connection for melanoma.

- The Committee welcomed the decision of Governments at the International Conference on Chlorofluorocarbons in Munich 6 - 8 December 1978, to reduce chlorofluoromethane emissions significantly.

- The Committee gave a number of recommendations concerning further research and monitoring to reduce the existing uncertainties.

- The WMO and WHO, with the support of UNEP, are continuing internationally coordinated studies of measurements of atmospheric constituents and health evaluation.

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